

# Reexamining Empathy in Autism: The Role of Empathic Disequilibrium in Autism and Autistic Traits

**Ido Shalev**

Ben-Gurion University of the Negev <https://orcid.org/0000-0002-2034-4527>

**Varun Warriar**

Cambridge University: University of Cambridge

**David M Greenberg**

Bar-Ilan University

**Paula Smith**

Cambridge University: University of Cambridge

**Carrie Allison**

Cambridge University: University of Cambridge

**Simon Baron-Cohen**

Cambridge University: University of Cambridge

**Alal Eran**

Ben-Gurion University of the Negev

**Florina Uzefovsky** (✉ [florina@bgu.ac.il](mailto:florina@bgu.ac.il))

Ben-Gurion University of the Negev <https://orcid.org/0000-0003-4571-2514>

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## Research

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# Abstract

**Background:** While many autistics report feelings of excessive empathy, their experience is not reflected by most of the current literature, which typically, but not always, suggests that autism is characterized by intact emotional empathy and reduced cognitive empathy. To try and bridge this gap in empirical findings and with respect to individuals' experiences, we examined a novel conceptualization of empathy termed empathic disequilibrium, i.e., the imbalance between emotional and cognitive empathy. Empathic disequilibrium was previously found to predict autistic traits in non-autistic population, suggesting it is an important empathy measure. Here, we aimed to extend the generalizability of empathic disequilibrium to the autistic population and to provide a better analytical approach to examine this construct.

**Methods:** We analyzed self-reports of empathy and autistic traits in a large cohort ( $N = 4,914$ ) of autistic and non-autistic individuals. We applied a polynomial regression with response surface analysis to examine empathic disequilibrium and total empathy as predictors of an autism diagnosis and autistic traits.

**Results:** Total empathy and empathic disequilibrium each predicted autism. There was a higher probability for diagnosis in individuals with lower total empathy, but also in individuals with higher emotional relative to cognitive empathy. Linear and non-linear patterns linked empathy, empathic disequilibrium, and autistic traits and diagnosis, with empathic disequilibrium being more prominent in females.

**Conclusions:** Empathic disequilibrium might allow for a more nuanced and sensitive understanding of empathy and its link with autism. This study provides empirical evidence that empathic disequilibrium is at least as informative as empathy for assessing autism, and offers a novel analytical approach for examining the role of empathy at the phenomenological level.

## Background

Our ability to understand and respond to each other's feelings, termed empathy, is crucial for social communication and allows us to establish and maintain social relationships [1, 2]. Atypicalities in empathy are a core feature of autism, a condition characterized by difficulties in social communication [3–6]. Autism is characterized by intact emotional empathy (EE) and reduced cognitive empathy (CE) [7, 8]. Yet mixed findings [9] suggest a more complex role for empathy in autism. The imbalance between cognitive and emotional components of empathy, termed empathic disequilibrium (ED), is associated with autistic traits beyond these components independently [10]. Here we extend our findings to adults with and without an autism diagnosis and use response surface analysis to characterize the relationship between autism, ED, and empathy in a more nuanced way.

Empathy is the ability to understand another's emotions and respond to them with an appropriate emotion while maintaining a self-other distinction [11]. Empathy includes both emotional and cognitive components. EE is the ability to respond to another's mental states with an appropriate emotion while maintaining self-other distinction, and CE is the ability to recognize what another person is feeling [7]. The two empathy components are rooted in distinct yet interrelated neurobiological and evolutionary mechanisms, and have different developmental and neural trajectories [12, 13]. For instance, EE appears very early in life and remains stable or increases slightly during the second year of life. On the other hand, CE, which is more susceptible to socialization agents (e.g., family environment), seems to develop later in life than EE and increases during the second and third years of life, as well as later in life [8, 14–17]. Similarly, a double dissociation between the two components is suggested by empathy manifestations in clinical conditions. The psychiatric condition of antisocial personality disorder is a case where individuals are usually described as having intact CE but impaired EE, and autism is a different condition where an individual typically shows intact EE but impaired CE, suggesting double dissociations are possible [18]. However, whether EE and CE can be definitively disentangled with any clarity is debated, and both components together facilitate understanding of other's behaviour and responding to it appropriately [2], and as such, play a fundamental role in shaping social communication.

Impairments in social communication and behaviour are core features of autism. Autism is characterized by social interaction and communication difficulties, accompanied by repetitive and restrictive behaviours with onset during early development [19]. Considering the fundamental role empathy plays in social behaviour and communication [2], atypicalities in empathy have been suggested to be a hallmark of autism [7].

**EE and CE in autism.** Many empirical findings show impaired CE and intact EE in autism [20, 21]. Yet other studies show mixed results [4, 22, 23]. For example, one study found that young autistic children displayed EE less frequently than non-autistic children [22]. Another study used a common behavioural task to measure CE and classified autistic individuals into five separate subgroups, two of whom did not differ in CE from non-autistic individuals [9]. These mixed findings hinder our ability to understand the behavioural and biological mechanisms of empathy and its role in autism.

**Empathic disequilibrium (ED).** It is important to note that almost all studies of empathy in autism examined the role of CE and EE independently of each other. However, CE and EE have also been shown to influence and regulate each other [24–26]. For example, CE-related brain regions interact with EE-related brain regions, particularly during complex social situations in which additional processing is needed to jointly engage EE and CE [26]. As we constantly encounter complex and relatively ambiguous social situations, these studies suggest that maintaining a balance between EE and CE is key for an adaptive and appropriate social response, leading to effective social communication. The possible role of the *balance* between EE and CE has been overlooked in previous studies, leaving some open questions about what happens when this joint regulation is altered and whether it might explain the mixed findings above.

For example, some individuals might show average CE, but in combination with higher EE, this creates an empathic imbalance, which might relate to signs of autism. To examine this possibility, we use the term ED, relating to the level of imbalance between CE and EE [10]. We previously found that the level of imbalance between CE and EE, and not each trait independently, predicted autistic traits in non-autistic individuals, even when controlling for their total empathy. Specifically, we showed that autistic traits were elevated in a group of individuals with relatively higher EE than CE (EE-dominance group) and found that EE-dominance was related to social aspects relevant to autism, such as alexithymia; but not to the restrictive and repetitive interests, such as systemizing [10]. These findings provide empirical evidence for the notion that an imbalance between CE and EE might contribute to some autistic symptoms [27].

The current work extends these findings and explores the relevance of ED to clinically diagnosed autistic individuals. Furthermore, in our previous paper, we used a difference score between standardized CE and standardized EE to measure ED while controlling for total empathy. This method has several limitations [28–30], but most importantly, it does not allow for the simultaneous investigation of both equity and inequity between EE and CE and their relation to an outcome.

To address these issues, we used polynomial regression with response surface analyses (PRRSA) [28, 31]. PRRSA visualizes the three-dimensional (in)congruency between variables and assesses their association with an outcome variable in a statistically valid and comprehensible way. Congruency is assessed via examination of the line of congruence (LOC), representing the degree to which similarity between variables is associated, both linearly and curvilinearly, with an outcome variable (see the blue line in Figure 1). Incongruency is measured using the line of incongruence (LOIC), which examines whether and how the discrepancy between two variables is related to an outcome (see the black line in Figure 1).

In this research, PRRSA allowed the examination of both ED, represented by the LOIC, and total empathy (which comprises both EE and CE), represented by the LOC, while considering the contribution of EE and CE separately. Using PRRSA, we examine whether equilibrium and disequilibrium between emotional and cognitive empathy (measured using validated self-report questionnaires) predict autism diagnosis and autistic traits (separating social and non-social aspects). Based on our previous findings [10], we hypothesized that both total empathy and ED, favouring EE, will predict autism and traits related to the social aspects of autism. In contrast, ED, favouring CE, will predict non-social aspects related to autism (e.g., systemizing). Furthermore, as ED also shows average sex differences, we expected females on average to show a higher tendency towards EE-dominance, relative to males.

## Methods

### Participants:

Participants were 1,905 individuals diagnosed with autism and 3,009 non-autistic controls (see Table 1 for descriptive statistics) recruited via the Cambridge Autism Research Database (CARD). Participants

self-reported their diagnosis (including specific details, such as date of diagnosis, which is used as a validity check for diagnostic status), age, and birth sex. Autistic and non-autistic participants then completed a battery of questionnaires. The non-autistic group showed elevated (yet in the typical range) autistic traits, and 193 individuals exceeded the autism cut-off of the Autism-Spectrum Quotient [32], suggesting that this group, although undiagnosed, shows slightly elevated features of autism.

Table 1  
Descriptive statistics.

	Non-autistic		Autism	
	Females	Males	Females	Males
N	2246	763	1027	878
Age	38.5 (11.5)	37.6 (14.5)	35.6 (11.9)	38.2 (13.9)
Autism quotient	17.1 (8)	19.8 (8.3)	39.2 (6.45)	37.9 (7.2)
Systemizing quotient	53.4 (20.8)	68 (22.4)	77.4 (24.2)	81.6 (25)
Overall empathy	49.6 (14.2)	39.5 (14.7)	19.9 (10.6)	17.4 (10.6)
Emotional empathy	6.57 (2.37)	4.89 (2.53)	3.65 (2.69)	2.91 (2.46)
Cognitive empathy	6.47 (2.66)	5.03 (2.92)	1.51 (2.06)	1.25 (1.96)
Descriptive statistics comparing autistic to non-autistic individuals, stratified by sex. Mean and standard deviation (in parenthesis) are reported.				

## Measures:

*Empathy.* Empathy was measured using the Empathy Quotient (EQ) [7]. The questionnaire consists of 60 items (40 empathy items and 20 filler items) on a 4-point scale. On each empathy item, a person can score 2, 1, or 0. Two three-factors structures are commonly used in the EQ to tap cognitive, emotional, and social skills aspects of empathy [33, 34]. To decide which of the two classifications provide the best fit for the specific data used, we conducted confirmatory factor analysis using lavaan package in R [35]. This analysis revealed a reasonable fit for both Lawrence's 28-items three factors and Muncer and Ling's 15-items three factors, but as the latter showed better fit indices (see Table 2), we chose to calculate EE and CE scores using Muncer and Ling's classification [33].

Table 2  
Confirmatory factor analysis of the Empathy Quotient.

Model	Items	Goodness of fit indices						
		$\chi^2$	df	$\chi^2/df$	RMSEA	-2 Log Likelihood	AIC	BIC
Lawrence and Shaw	28	9097	347	26.22	0.07	266712	266830	267216
Muncer and Ling	15	1773	87	20.38	0.06	149985	150051	150267

Confirmatory factor analysis and model fit parameters of Lawrence and Shaw, and Muncer and Ling Empathy Quotient classification.

We did not include the subscale tapping social skills (which is part of the original three-factor classification) as it does not directly relate to EE and CE. Using these classification, EE and CE were found to be positively correlated ( $r = 0.59, p < 1 \times 10^{-100}$ ). Following Fleenor et al. [36] recommendation and in line with our previous study [10], EE and CE were standardized (separately). Moreover, to create an easily interpretable measure, before dividing both measures by the standard deviation of the total sample, both EE and CE were centered based on the mean of the control group. Thus, the scores reflect the standardized score of CE and EE, relative to the mean of the non-autistic population.

*Autistic traits.* Autistic traits were measured using the Autism Spectrum Quotient (AQ) [32]. This questionnaire consists of 50-items measuring autistic traits in the general population. Responses are scored using a binary system, where an endorsement of the autistic trait (either mildly or strongly) is scored as 1, while the opposite response is scored as 0. Scores are then summed up leading to a maximum score on the AQ of 50. The AQ can also be divided according to five domains: 'social 'skills', 'attention 'switching', 'attention to 'detail', "communication', and "imagination'. We also measured systemizing, which is the drive to analyze or construct systems, and is an autism-related feature of the non-social domain of autism [37, 38]. Systemizing was measured using the Systemizing Quotient [39], a 60 items (40 systemizing items and 20 filler items) questionnaire with a 0-2 rating scale, with higher scores representing higher systemizing.

*Statistical analyses: Sex differences analysis.* A 2x2 ANOVA was conducted examining sex, diagnosis, and their interaction as predictors of ED. ED was calculated by subtracting standardized CE from standardized EE [10].

*Response surface analysis of empathy.* To examine ED and its applicability in autism, we applied PRRSA [28, 31]. PRRSA tested both the linear and curvilinear pattern of total empathy, defined as the LOC, and of ED, defined as the LOIC, using a polynomial regression between EE and CE as described using the following equation (1) :

$$(1) Z = b_0 + b_1CE + b_2EE + b_3CE^2 + b_4CE \times EE + b_5EE^2 + e$$

To interpret the surface of the polynomial regression, regression coefficients are used to extract four surface parameters, as follows:

1. The linear association between total empathy and an outcome variable ( $a1 = b1 + b2$ ).
2. The curvilinear association between total empathy and an outcome variable ( $a2 = b3 + b4 + b5$ ).
3. The linear association between ED and an outcome variable ( $a3 = b1 - b2$ ).
4. The curvilinear association between ED and an outcome variable ( $a4 = b3 - b4 + b5$ ).

Therefore,  $a1$  and  $a2$  reflect the association between total empathy and an outcome, while  $a3$  and  $a4$  reflect the association between ED and an outcome.

*Autism prediction using PRRSA.* We first wanted to examine if the polynomial regression surface created using EE and CE and its derived total empathy (i.e.,  $a1$  and  $a2$ ) and ED (i.e.,  $a3$  and  $a4$ ) parameters predict autism diagnosis. To do so, we conducted a polynomial logistic regression with autism diagnosis as a binary outcome. We also examined whether the surface parameters differed between the sexes. Age was used as a covariate.

*Autistic traits prediction using PRRSA.* Using PRRSA, we also examined whether total empathy and ED predicted autistic traits and whether surface parameters differed between autistic and non-autistic individuals. To do so, we conducted a polynomial regression analysis using EE and CE for AQ and SQ as outcome variables (separately). Differences in surface parameters were investigated between autistic and non-autistic individuals. Age and sex were used as covariates. We also conducted polynomial regression analyses for each of the five AQ subscales separately (see supplementary information).

All analyses were carried out using R v4.0.3 'stats' package [40]. RSA plots were produced using the RSA package in R [41].

## Results

*Sex differences in ED.* Before applying PRRSA, we examined whether males and females differ on average in ED, and whether sex interacts with diagnosis. An ANOVA revealed significant main effects for sex ( $F(1,4910) = 29.41, p = 6 \times 10^{-8}, \eta_p^2 = 0.006$ ) and diagnosis ( $F(1,4910) = 393.1, p = 4 \times 10^{-79}, \eta_p^2 = 0.074$ ), with no interaction effect ( $F(1,4910) = 0.52, p = 0.47$ ). To better understand these findings, we conducted post-hoc one-sample  $t$ -test analyses to examine whether the mean of each group differs from a balanced empathy score (CE equals EE; ED = 0). Autistic males and females differed significantly from equilibrium ( $t(877) = -13.54, p = 5 \times 10^{-38}$  for males;  $t(1026) = -20.905, p = 4 \times 10^{-81}$  for females) showing higher EE than CE. Non-autistic males differed from equilibrium showing higher CE than EE ( $t(762) = 2.84, p = 0.005$ ), while non-autistic females did not show significant differences from equilibrium ( $t(2245) = -1.76, p = 0.08$ ). Results are shown in Figure 2.

*Response surface analysis of empathy.* We next examined how total empathy and ED predict autism diagnosis and autism-related traits using PRRSA models. Residuals of all the models tested were normally distributed.

*Predicting autism diagnosis.* The overall polynomial regression model predicted autism diagnosis ( $R^2 = 0.52, p < 1 \times 10^{-100}$ ) in males and females (see Table 3 and Figure 1).



Table 3  
Polynomial regression with response surface parameters predicting autism diagnosis.

Effect	Males			Females			
	Estimate	p-value	OR [95% CI]	Estimate	p-value	OR [95% CI]	
CE	-0.87 (0.12)	5x10 <sup>-13</sup>	0.42*** [0.33 - 0.52]	-1.42 (0.11)	3x10 <sup>-37</sup>	0.24*** [0.19 - 0.3]	
EE	0.034 (0.11)	0.77	1.03 [0.82 - 1.3]	-0.18 (0.09)	0.045	0.84* [0.7 - 0.99]	
CE <sup>2</sup>	0.45 (0.07)	9x10 <sup>-11</sup>	1.57*** [1.37 - 1.79]	0.26 (0.065)	0.000065	1.3*** [1.14 - 1.47]	
EE <sup>2</sup>	0.22 (0.06)	0.0007	1.25** [1.09 - 1.42]	0.15 (0.05)	0.003	1.17** [1.05 - 1.29]	
CE x EE	-0.095 (0.075)	0.2	0.91 [0.78-1.05]	-0.045 (0.07)	0.525	0.95 [0.83 - 1.1]	
Response surface parameters							<b>Group Comparison (p – value)</b>
a1	-0.84 (0.15)	2x10 <sup>-8</sup>	0.43*** [0.24 - 0.675]	-1.6 (0.12)	9x10 <sup>-39</sup>	0.2*** [0.14 - 0.28]	0.00008***
a2	0.57 (0.08)	1x10 <sup>-11</sup>	1.78*** [1.4 - 2.25]	0.37 (0.076)	1x10 <sup>-6</sup>	1.45*** [1.17 - 1.79]	0.073
a3	-0.9 (0.18)	9x10 <sup>-7</sup>	0.4*** [0.24 - 0.675]	-1.24 (0.16)	8x10 <sup>-15</sup>	0.29*** [0.18 - 0.45]	0.16

Autism diagnosis prediction using polynomial regression with response surface analysis (PRRSA) analysis and parameters statistics of empathy. Sex differences are depicted.

\* $p < 0.05$ , \*\* $p < 0.005$ , \*\*\* $p < 0.0005$

	Males		Females				
a4	0.77 (0.15)	$3 \times 10^{-7}$	2.15*** [1.42 - 3.26]	0.46 (0.14)	0.0008	1.585** [1.08 - 2.32]	0.13
Autism diagnosis prediction using polynomial regression with response surface analysis (PRRSA) analysis and parameters statistics of empathy. Sex differences are depicted.							
* $p < 0.05$ , ** $p < 0.005$ , *** $p < 0.0005$							

*Sex was associated with autism with females showing decreased probability for diagnosis (OR = 0.6 [0.43 – 0.83, 95% CI],  $p = 0.002$ ). A very small sized yet significant association between age and decrease in probability was found (OR = 0.99 [0.986 – 0.998, 95% CI],  $p = 0.02$ ).*

*Total empathy - Lower total empathy was associated with an autism diagnosis, showing both a linear (a1) and a curvilinear (a2) association. The linear effect of total empathy was stronger for females than for males ( $t = -3.95$ ,  $p = 0.00008$ ).*

*ED - ED also significantly predicted autism, with an effect size that was similar to that of total empathy. The probability for autism diagnosis was higher for individuals whose EE was higher than their CE (negative a3). A significant curvilinear association shows that autism probability increases more sharply as ED increases (positive a4).*

*Autistic traits prediction.* The overall polynomial regression of empathy also predicted autistic traits ( $R^2 = 0.75$ ,  $p < 1 \times 10^{-100}$ ) measured using the AQ [32] in the autistic and non-autistic populations (see Table 4 and Figure 3).

Table 4

## Polynomial regression with response surface parameters predicting Autism-Spectrum Quotient.

	Autism			Non-autistic			
Effect	Estimate (SE)	p-value	beta	Estimate (SE)	p-value	beta	
CE	-3.62 (0.46)	$5 \times 10^{-15}$	-0.265***	-3.15 (0.13)	$5 \times 10^{-115}$	-0.19***	
EE	-0.5 (-0.37)	0.17	-0.03	-1.14 (0.14)	$3 \times 10^{-16}$	-0.07***	
CE <sup>2</sup>	0.18 (0.22)	0.425	0.027	1.6 (0.13)	$5 \times 10^{-36}$	0.125***	
EE <sup>2</sup>	0.235 (0.14)	0.1	0.03	0.44 (0.12)	0.0002	0.04***	
CE x EE	0.265 (0.22)	0.24	0.03	-0.45 (0.14)	0.0015	-0.03**	
Response surface parameters							<b>Group Comparison (p -value)</b>
a1	-4.13 (0.52)	$3 \times 10^{-15}$	-0.295***	-4.29 (0.15)	$1 \times 10^{-163}$	-0.26***	0.76
a2	0.68 (0.24)	0.036	0.087*	1.59 (0.14)	$1 \times 10^{-28}$	0.135***	0.001**
a3	-3.11 (0.65)	$2 \times 10^{-6}$	-0.235***	-2 (0.14)	$3 \times 10^{-18}$	-0.12***	0.11
a4	0.15 (0.44)	0.74	0.027	2.5 (0.29)	$8 \times 10^{-18}$	0.195***	0.00001***
Parameters of the polynomial regression with response surface analysis (PRRSA) of EE and CE, predicting Autism-Spectrum Quotient score in autistic and non-autistic individuals.							
* $p < 0.05$ , ** $p < 0.005$ , *** $p < 0.0005$							

As expected, autism diagnosis was associated with higher autistic traits ( $\beta = 0.56$ ,  $p < 1 \times 10^{-100}$ ), and males showed higher autistic traits than females ( $\beta = 0.04$ ,  $p = 3 \times 10^{-7}$ ). Age was also associated with autistic traits ( $\beta = 0.03$ ,  $p = 0.000009$ ).

Total empathy - Lower total empathy was associated with higher AQ scores in autistic and non-autistic individuals, showing linear (a1) and curvilinear (a2) associations. The curvilinear association for total empathy was stronger for non-autistic than for autistic individuals ( $t = -3.3$ ,  $p = 0.001$ ).

ED - A linear association between ED and autistic traits was found for both autistic and non-autistic individuals, with higher EE-dominance predicting higher autistic traits (negative a3). A curvilinear

association of ED and autistic traits was also found for non-autistic individuals, which differed from the non-significant curvilinear effect of ED in autistic individuals ( $t = -4.43, p = 0.00001$ ).

PRRSA for each of the five AQ subscales were also examined and are reported in the supplementary information.

*Systemizing.* To examine the non-social domain of autism, we also measured systemizing – the drive to analyse and construct systems, using the SQ [39]. Autism diagnosis was associated with higher SQ score ( $\beta = 0.235, p = 3 \times 10^{-14}$ ), and males showed higher SQ scores than females ( $\beta = -0.14, p = 4 \times 10^{-25}$ ). Age was also associated with systemizing ( $\beta = 0.056, p = 0.00001$ ). The overall model of empathy was found to be predictive of systemizing traits ( $R^2 = 0.26, p < 1 \times 10^{-100}$ ) in autistic and non-autistic individuals. See details in Table 5 and Figure 4.

Table 5  
Polynomial regression with response surface parameters predicting Systemizing Quotient.

Effect	Autism			Non-autistic			Group Comparison (p-value)
	Estimate (SE)	p-value	beta	Estimate (SE)	p-value	beta	
CE	2.35 (1.69)	0.16	0.09	0.64 (0.48)	0.19	0.02	
EE	-2.28 (1.3)	0.0785	-0.08	-2.98 (0.5)	4x10 <sup>-9</sup>	-0.09***	
CE <sup>2</sup>	3.4 (0.81)	0.00003	0.26***	2.45 (0.45)	7x10 <sup>-8</sup>	0.1***	
EE <sup>2</sup>	1.32 (0.51)	0.009	0.09*	1.3 (0.43)	0.0025	0.05**	
CE x EE	-0.58 (0.79)	0.47	-0.04	-1.13 (0.51)	0.027	-0.04*	
Response surface parameters							
a1	0.07 (1.87)	0.97	0.01	-2.35 (0.54)	0.00002	-0.07***	0.21
a2	4.14 (0.84)	9x10 <sup>-7</sup>	0.31***	2.61 (0.51)	3x10 <sup>-7</sup>	0.11***	0.12
a3	4.63 (2.365)	0.05	0.17	3.62 (0.82)	0.00001	0.11***	0.685
a4	5.29 (1.57)	0.0008	0.39**	4.87 (1.03)	2x10 <sup>-6</sup>	0.19***	0.82
Parameters of polynomial regression with response surface analysis (PRRSA) of EE and CE, predicting Systemizing-Quotient score in autistic and non-autistic individuals.							
*p < 0.05, **p < 0.005, ***p < 0.0005							

Total empathy - In the autistic population, the curvilinear, but not linear, association was significant, with higher SQ scores predicted by high or low total empathy. In contrast, although not significantly different from the autistic group (see 'group 'comparison' statistics in Table 4), non-autistic individuals also showed significant linear and curvilinear association of small sized effects between total empathy and systemizing.

ED – In the autistic group, the curvilinear association was again significant, with higher SQ scores predicted by high or low ED. Although only nominally significant, linear association between ED and SQ showed a tendency towards higher SQ scores for autistic individuals whose CE is higher than EE. In the

non-autistic group, ED was associated linearly and curvilinearly with ED, with a tendency towards higher CE than EE predictive of SQ score.

## Discussion

In this study we investigated the independent role of ED and empathy in predicting autism diagnosis and autistic traits in autistic and non-autistic individuals. In line with our hypotheses, both total empathy and ED predicted autism, with a higher probability for diagnosis in individuals with lower total empathy and in individuals with higher emotional than cognitive empathy. Our data suggest linear and non-linear patterns linking empathy, ED, and autism diagnosis in autistic and non-autistic individuals; such complexity was also apparent in predicting autistic traits. We also found that a tendency towards EE-dominance (higher emotional than cognitive empathy) is more related to the social domain of autism (e.g., as measured by the social-related subscales of the AQ), while a tendency towards CE-dominance (higher cognitive than emotional empathy) is more related to the non-social domain (e.g., as measured by the SQ). In addition, while the relationship between ED and autism holds for both sexes, females across diagnostic groups showed a greater tendency towards higher EE than CE.

Investigating ED and total empathy simultaneously allowed us to show that both aspects of empathy are informative of autism diagnosis and autistic traits. Thus far, studies examining EE and CE separately resulted in inconsistent findings, suggesting each component of empathy by itself is not sensitive enough to characterize autism [4, 9, 22, 23]. The current approach to investigating empathy takes into account the relationship between EE and CE, and as such may shed light on some of these mixed findings. Based on our findings, mean differences between autistic and non-autistic individuals in CE or EE do not reflect the role of empathy in autism to the fullest. Indeed, we find that beyond overall empathy, the probability for autism diagnosis is associated with higher EE relative to CE (i.e., a tendency towards EE-dominance).

How would such an imbalance manifest? A person with ED towards EE-dominance might understand others' emotional states (CE) at the typical level, but her/his ability to experience and share in these emotions (EE) will be relatively higher. Smith [27] suggested that this state would cause overarousal, as the individual becomes overwhelmed with the other's emotions, resulting in the cognitive and behavioural characteristics of autistic individuals, which constitute an adaptive response to overarousal. This conceptualization coincides with the inner experience of some autistic individuals reporting "excess of empathy" [42]. Future research will need to validate this notion and examine it as a possible mechanism of action underlying the relationship between ED and autism.

The idea that empathy might be linked to overarousal in autism is also reflected by the non-linear associations between empathy (both total empathy and ED) and autism diagnosis and some autistic traits (see supplementary information for details). This finding is in line with the suggestion, although rarely examined empirically, that non-linear models are better suited for describing empathy in a nuanced way [43, 44]. In addition, some researchers suggest that extreme (high or low) levels of empathy can lead

to overarousal and worsen psychological functioning [43, 45]. If this is the case in autism – where problems in emotion-regulation are common [46, 47] - emotional dysregulation may be driven by ED or extreme levels of total empathy.

Regarding ED, our data show that the two types of ED (EE-dominance versus CE dominance) predict different domains of autistic behaviour in both autistic and non-autistic individuals: a tendency towards EE-dominance is associated with the social domain of autism, while a tendency towards CE-dominance is associated with the non-social domain of autism (such as systemizing). We found the same patterns in a non-autistic population [10]. Therefore, these results replicate our previous study and extend the generalizability and utility of the ED concept to autistic individuals.

Furthermore, the differences within the autistic group between individuals with a tendency towards EE compared to those with a tendency towards CE dominance highlights the heterogeneity characterizing the autistic spectrum [48]. It might also provide a new basis for stratifying autistic individuals, which is a means for understanding the heterogeneity of autism [49, 50]

We also observed average sex differences in relation to ED in autistic and non-autistic populations. These differences were prominent in autistic individuals showing that while both autistic males and females displayed higher EE than CE, this effect was more pronounced in autistic females. This is in line with our hypothesis [10] that ED might be of particular relevance to autistic females, a relatively under-studied population [51, 52], and could help differentiate a female presentation of autism.

## Limitations

Our study has several limitations. First, the sample used in our study consists of autistic individuals with average or above average intelligence (reflected indirectly in being able to participate in online studies) and so does not represent the entire autistic spectrum. Online studies also lead to an ascertainment bias, reflected by the relatively high proportion of autistic females in the sample, which is not representative of the typical higher male-to-female ratio in autism [51]. This limits our conclusions regarding sex differences in ED between autistic males and females. Furthermore, the non-autistic group also included family members of diagnosed individuals, suggesting the findings might be more representative of the broad autism phenotype, i.e., people who carry genetic liability for autism and/or display milder phenotypic features [53, 54]. Yet even in this population as a comparison group, we see significant differences with the autistic group.

Second, all measures used in our study are self-report questionnaires. Although these measures are validated and correlate with other behavioural measures [7, 32, 34, 39], they primarily reflect the participants' perception of their own functioning and ability. However, while observational methods offer rich information, empathy is largely an internally-experiential process that cannot be inferred from behaviour alone [55], suggesting that self-report measures are valuable tools for understanding empathy.

## Conclusions

This study provides empirical evidence that ED is at least as informative as empathy for the diagnosis of autism, and for predicting autistic traits in both autistic and non-autistic populations. By offering a novel way to examine the role of empathy in autism, ED promises to scaffold our understanding of the experience of some autistic individuals. By refining our understanding of the link between empathy and autism, targeting ED in future research may provide valuable clinical insights used for prognosis, diagnosis, and interventions in autism. Moreover, it can help delineate the nature of the mechanisms underlying empathy for all individuals.

## Abbreviations

EE, Emotional Empathy; CE, Cognitive Empathy; ED, Empathic Disequilibrium; PRRSA, Polynomial Regression with Response Surface Analysis; LOC, Line Of Congruence; LOIC, Line Of Incongruence; CARD, Cambridge Autism Research Database; EQ, Empathy Quotient; AQ, Autism-Spectrum Quotient; SQ, Systemizing Quotient.

## Declarations

**Ethics approval and consent to participate:** Ethical approval for the research database was obtained from the Psychology Research Ethics Committee (PREC), University of Cambridge, UK. Before participation, all participants signed informed consent.

**Consent for publication:** Not applicable.

**Availability of data and materials:** The dataset cannot be made publicly available as participants registered in the Cambridge Autism Research Database have not consented to this form of data sharing when they registered. However, researchers can contact the database managers who will on reasonable request share the anonymised data included in the study. Code used for all statistical analyses can be shared upon request.

**Competing Interests:** The authors declare that they have no competing interests.

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**Author Contributions:** IS conducted the analyses. IS, FU and AE designed the study and the theoretical formulation described in it. IS and FU wrote the paper, and AE provided critical comments on it. SBC, PS, and CA, collected the data. SBC, VW and DMG revised the paper and provided critical comments on the paper.

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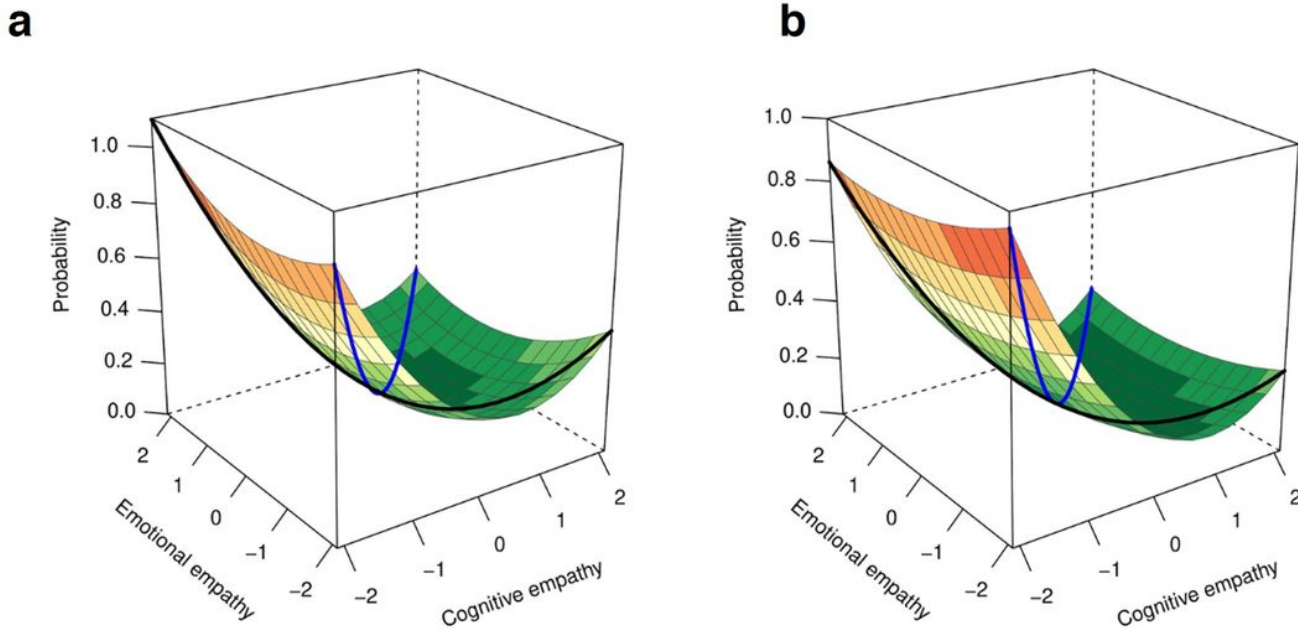
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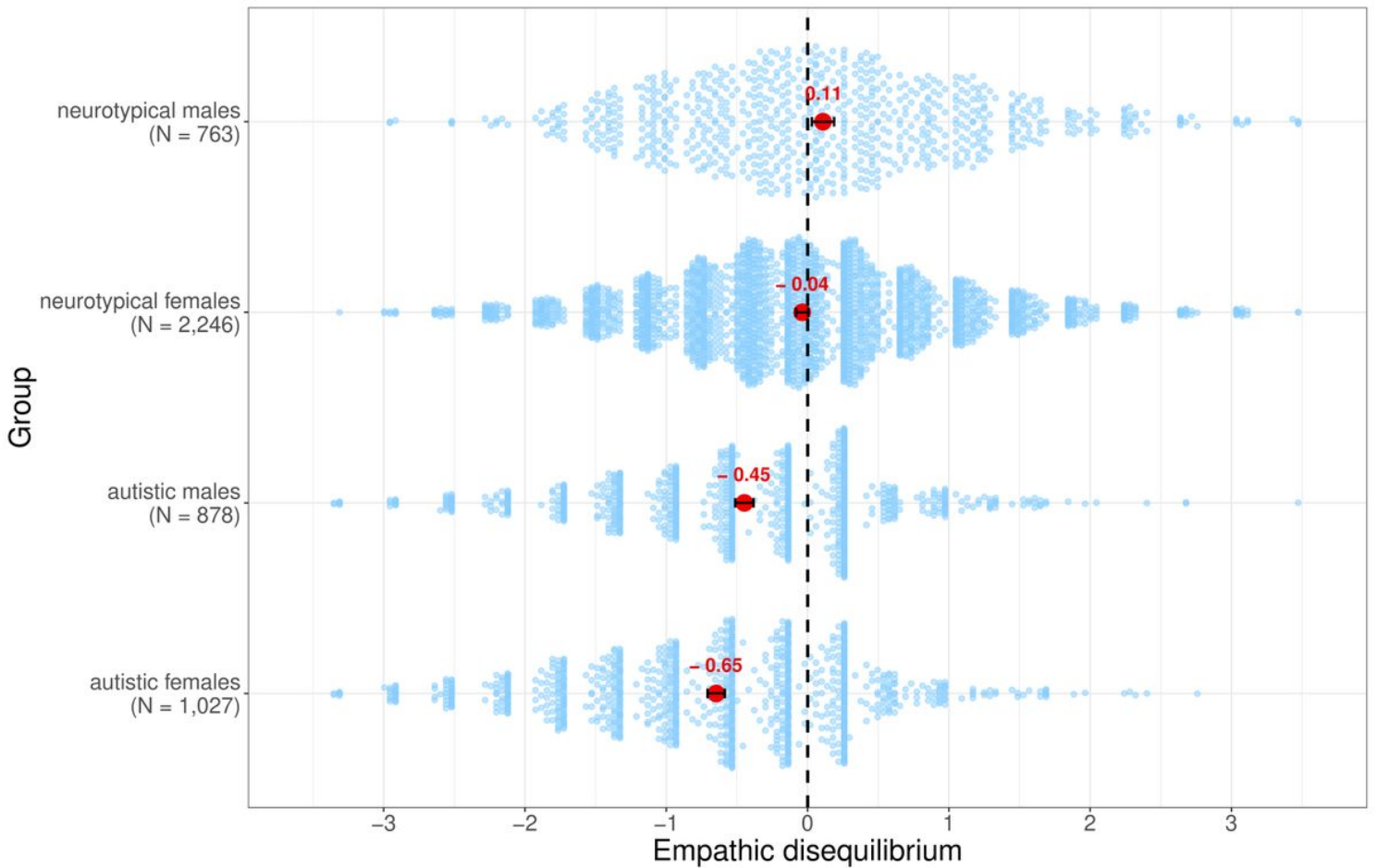
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## Figures



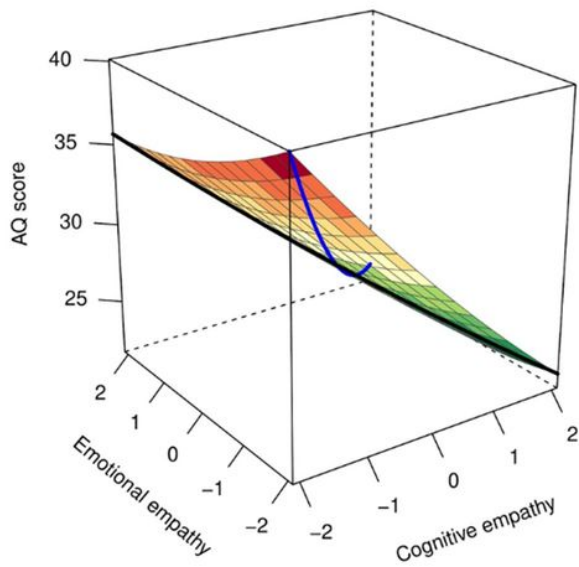
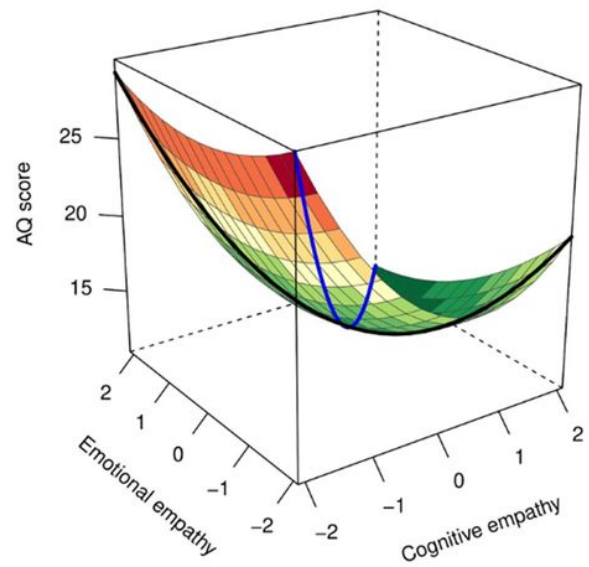
**Figure 1**

Polynomial regression plot predicting the probability of autism diagnosis. A plot of the polynomial regression with response surface analysis (PRRSA) of emotional and cognitive empathy, predicting the probability of autism diagnosis. The black line represents empathic disequilibrium and the blue line represents total empathy. The left panel (a) shows the PRRSA for males (N = 1,641) while the right panel (b) for females (N = 3,273).

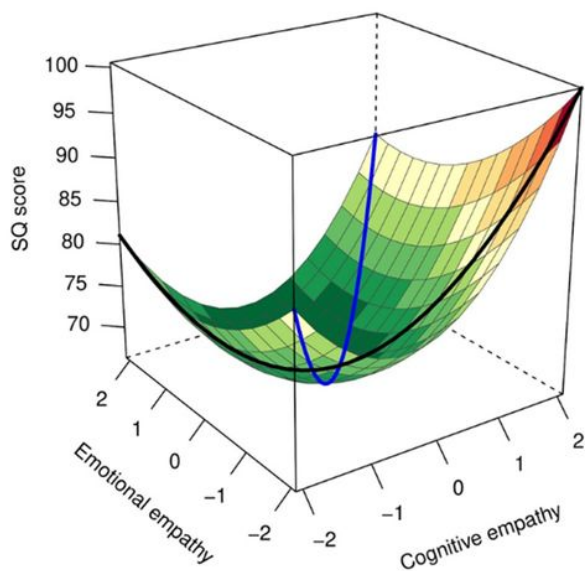
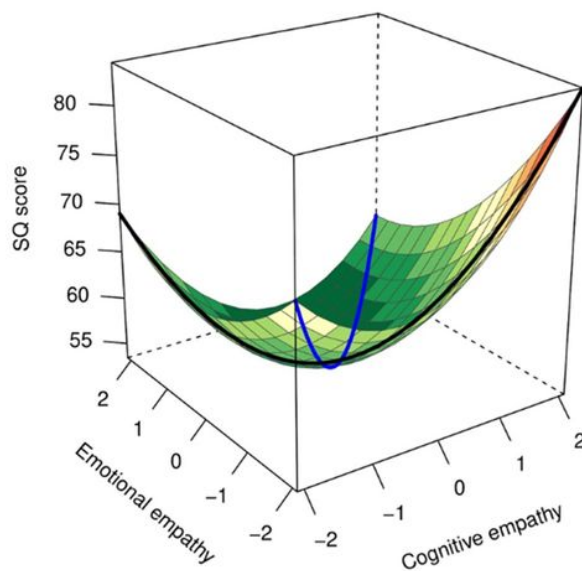


**Figure 2**

Sex and diagnosis differences in empathic disequilibrium (ED). The mean of each group appears in red. 95% confidence intervals of each group are depicted. Positive values of ED (on the x-axis) represent higher cognitive than emotional empathy. Negative values represent higher emotional than cognitive empathy. The dashed line represents the point of no difference between cognitive and emotional empathy.

**a****b****Figure 3**

Polynomial regression plot predicting Autism-Spectrum Quotient (AQ). A plot of the polynomial regression with response surface analysis (PRRSA) predicting AQ scores, predicting autism-quotient score in a. autistic individuals (N = 1,905), and b. non-autistic individuals (N = 3,009). The black line represents ED and the blue line represents total empathy.

**a****b****Figure 4**

Polynomial regression plot predicting Systemizing Quotient (SQ). A plot of the polynomial regression with response surface analysis (PRRSA) predicting systemizing-quotient (SQ) score in a. autistic individuals (N = 1,809), and b. non-autistic individuals (N = 2,803). The black line represents ED and the blue line represents total empathy.

## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [ReexaminingempathyinautismSIMolecularAutism.docx](#)